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SOIL WATER DEPLETION BY LODGEPOLE PINE ON GLACIAL TILL

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ABSTRACT

*Soil water depletion was measured on small, paired plots of cut and uncut lodgepole pine (*Pinus contorta* Dougl.). Neutron measurements were made to a depth of 3 m on two different soils of glacial origin. Soils on the cut plot contained from 3 to 11 cm more water than the adjacent uncut plot at the end of each summer after cutting. These changes in soil water regimen were restricted to the surface 2 m of soil. The treatment effect should persist for several years, until deep-rooted vegetation is completely reestablished on the site.*

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KEYWORDS: soil water relation; neutron moisture meter; clearcutting; water yield; *Pinus contorta* Dougl.; Uinta Mountains, Utah; glacial soils

The effect of management practices on water resources is a vital consideration in resource management. Water relation studies in many vegetation types clearly indicate that harvesting or other means of removing vegetation affects the soil water regimen of the site and can affect the amount and timing of water yields. It is important that land managers be able to assess these impacts for a wide variety of conditions.

Lodgepole pine (*Pinus contorta* Dougl.) is an important, widespread timber type in the western United States and Canada. The areal distribution of commercial lodgepole pine stands in Utah is 227,843 ha (563,000 acres), small compared to other western States, but third among Utah's timber types (Choate 1965). Its range is mostly restricted to the Uinta Mountains in the northeastern corner of the State, where average precipitation usually exceeds 76 cm (Hutchison and others 1965).

In Utah and many other areas, extensive stands are located on soils developed on glacial and on fluvial-glacial deposits.

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Several studies have explored the water relations of lodgepole pine growing on volcanic soils in Washington and Oregon (Bishop 1961; Herring 1968; and Dahms 1971), but little work has been reported on glacial tills. One deterrent has been the difficulty of soil moisture measurement in stony soils. The hydrologic effects of patch cutting lodgepole pine were studied in Colorado at about the same time this study was being conducted (Dietrich and Meiman 1974). That study was more intensive and of a greater scope than the study reported here. It included comparative soil-water measurements from small, paired clearcut and control plots at about 2,700-m m.s.l. on soils derived from gneiss-schist parent materials. A water balance was developed for each plot and the effect of cutting on the water yield of the site was estimated.

The scope of the study reported here is limited, but it provides an insight into soil water conditions under lodgepole pine growing in glacial tills.

AREA DESCRIPTION AND METHODS

The study area is on the north slope of the Uinta Mountains, south of Mountain View, Wyoming, at an elevation of about 3,040 m. Two sites, about 1.6 km apart, were selected in the upper Gilbert Creek drainage on contrasting, but representative, soil types. Both sites were essentially level, thus eliminating the effects of slope and aspect on water relations of the plots.

One site was on a broad ridge, where deep, stony, well-drained, sandy loam soil had developed on glacial till outwash (fig. 1). This soil overlays a thick deposit of stony, clayey, cobbly material of preglacial origin. The lodgepole stand was dense, with a basal area of 37 m^2/ha (160 ft^2/acre) and average tree height of 9 m. Average tree diameter was 11-cm d.b.h. with occasional trees measuring 25- to 28-cm d.b.h. Understory vegetation was sparse, making up about 1 to 2 percent of the ground cover, 75 to 80 percent of which was composed of litter (fig. 2). Roots were observed throughout the surface 2 m of soil and may extend to greater depths.

Figure 1.--The rocky soils of the ridge site are shown in this 4-m-deep road cut. The study site is about 30 m into the interior of the lodgepole stand.

Figure 2.--This view of the control plot at the ridge site illustrates the dense stand characteristics and near absence of understory vegetation.

The second site, adjacent to a large meadow, had deep, moderately-to-imperfectly drained clayey soil. Surface soil was silty clay loam with a heavy clay layer at about 1 m and a stony clay loam substratum. Occasional roots were observed below the clay layer. Trees were larger than at the ridge site; average height was 12 m and the mean d.b.h. was 25 cm with a basal area of 50 m^2/ha (216 ft^2/acre). Occasional trees measured 50 to 63-cm d.b.h. Understory vegetation, which comprised 8 to 10 percent of the ground cover, was denser than at the ridge, and had a greater variety of grasses and forbs. The litter layer was also thick at this site.

Two plots were located at each of the two study sites. Following a season of pretreatment measurements, one plot at each site was clearcut; logs were removed from the site and slash was piled and burned. Clearings were about 900 m^2 (0.22 acre). A trench, about 1.5 m deep, was dug around each clearcut plot to sever roots from the adjacent stand.

Four neutron access tubes about 3 m apart were installed to a minimum depth of 3 m near the center of each plot. Holes were drilled with a track-mounted rock drill coupled to a 9.9 m^3 (350 ft^3) air compressor. Soil water content was determined from measurements made with a Nuclear-Chicago neutron probe[2] beginning at a depth of 15 cm and continuing at intervals of 30 cm thereafter to the bottom of the hole. Measurements were taken shortly after snowmelt (June), in midsummer, and in mid-September of each of the three study years. Measurements were made 1 year prior to treatment and 2 years after cutting.

[2]Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture of any commercial product or service.

Some difficulty was encountered while installing access tubes in the dry, stony soils at the ridge site. Small stones and rock fragments were dislodged, jamming the drill bit. If excessive redrilling and blowing were required to free the drill steel, the hole was abandoned because of the possibility of creating voids and unduly disturbing sidewalls, which would cause measurement errors. The effects of rocks and voids on soil water measurements have been discussed by Koshi (1966) and Richardson and Burroughs (1972).

Drilling problems were not excessive, even under these difficult conditions. Some problems might be eliminated by drilling when soils are damp or by drilling inside a casing slightly larger than the drill bit. The casing could then be used in lieu of the normal access tubing or withdrawn after placement of access tubes. The extra large cavity would require careful backfilling. Either method would require testing and calibration.

Neutron probes need not be recalibrated for differing soil characteristics if data are used to compare differences in soil water content caused by treatment of adjacent plots. Calibration is essential if precise measurement of water content is desired. Pretreatment measurements, even those of short duration, provide valuable information as to inherent variability between plots and holes and disclose possible sources of error.

Precipitation was monitored at a climatic station located about midway (0.8 km) between sites. Snow depth and water equivalent was measured along a line transect through each plot to verify anticipated changes in snow accumulation patterns due to cutting. Snow measurements were made only once, during the peak accumulation period in April 1971.

RESULTS

Soil water depletion.--Soil water increased on both cut plots during each of the two summers following treatment. Average water depletion, the difference between June and September water content, is shown in figure 3.

Pretreatment measurements indicate an inherent difference of approximately 3.7 cm in average water depletion between the two ridge plots. The difference in seasonal water depletion between these plots increased to 14.8 and 12.3 cm during the 2 years after cutting. If pretreatemnt differences are considered constant, the water loss from the cut plot should be reduced to 11.1 and 8.6 cm, respectively, during the first and second summers after cutting. This change was confined to the surface 2 m, in which water content at the end of the summer was increased by 1 to 2 cm of water per 30 cm of soil depth. Little change in water content was noted below this depth.

There was little difference in water depletion between the two meadow plots prior to cutting. After treatment, water loss on the control plot was 3.1 to 3.5 cm greater than on the cut plot, considerably less than at the ridge site. All changes in water content on the meadow plots were confined to the surface meter of soil.

Table 1 lists average water content for all plots at the start and finish of the 3-year-study measurement periods. These data are based on factory calibration curves for the neutron probe and are subject to error when used in rocky soils. They are included to illustrate annual moisture variations and the range of water contents encountered in this study.

Figure 3.--A comparison of average water depletion (average of four holes to a depth of 3 m) for two glacial soils before and after clearcutting lodgepole pine.

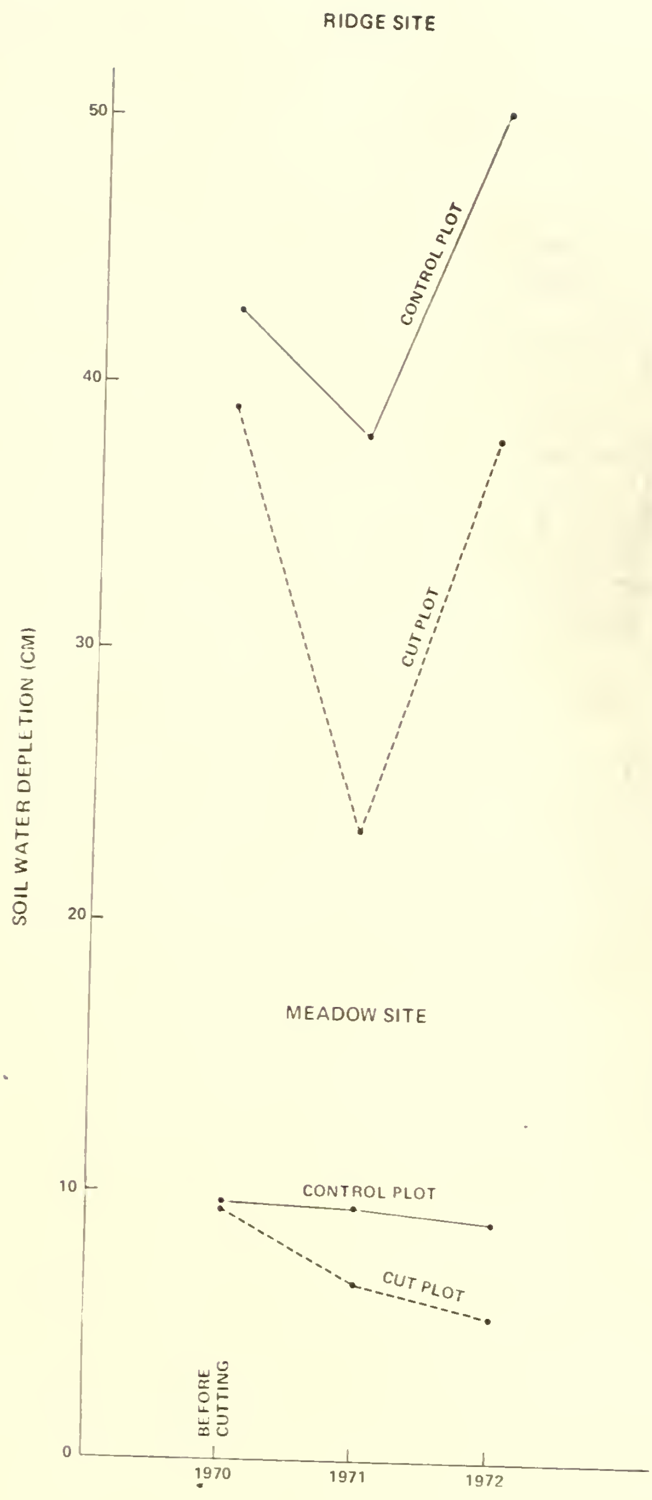

Table 1.--*Average soil water depletion*[1] *from cut and uncut lodgepole pine plots*

Item	1970 Uncut	1970 To be cut	1971 Uncut	1971 Cut	1972 Uncut	1972 Cut
	Centimeters					
RIDGE SITE						
Initial water content	85.9	75.4	80.2	71.0	87.1	79.2
Final water content	43.2	36.4	42.3	47.9	36.9	41.3
Depletion	42.7	39.0	37.9	23.1	50.2	37.9
Depletion difference	3.7		14.8		12.3	
MEADOW SITE						
Initial water content	93.8	91.1	92.5	91.3	90.4	89.6
Final water content	84.4	81.9	83.3	85.2	81.8	84.5
Depletion	9.4	9.2	9.2	6.1	8.6	5.1
Depletion difference	0.2		3.1		3.5	

[1] Average water content of four access holes to a depth of 3 m.

Greater statistical sensitivity could be achieved by increasing the number of sampling points per plot. However, the high cost of measurements and installing access holes usually prohibits intensive sampling in forest soils, which usually have a high inherent variability. Within-plot variance was greatest at the ridge site, where soils are stony and more heterogeneous than at the meadow. Using the variance indicated by the pretreatment measurements, we would need at least 12 sample points per plot at the meadow and 57 sample points per plot at the ridge to measure mean depletion within ±2.5 cm at the 95 percent confidence level.

Initial water contents for all holes varied slightly each year. At the ridge site, water content of the cut plot decreased until midsummer and then remained unchanged for the rest of the season. Water content of the control plot continued to decrease until the final measurement in mid-September. The effects of cutting at the meadow site were less dramatic. Water content decreased slightly throughout the season on both plots, but the rate of water loss was greater on the uncut plot.

Evapotranspiration.--Summer rainfall in the Intermountain West is generally light, seldom recharges more than the surface several centimeters of soil, and is rapidly lost because of high evapotranspiration. Therefore, rainfall between measurement dates is usually added to the measured water depletion to obtain an estimate of growing season evapotranspiration from the site. Summer rainfall varied at this study site from 18 cm in 1970 and 1971 to 13 cm in 1972. Addition of this rainfall to the water depletion of each plot increases the estimated total water loss from each plot, but does not alter the differences between plots attributed to the cutting treatment.

Snow accumulation.--Many studies have shown that small forest clearcuts influence the accumulation of snow. Interception of snow by tree canopies is eliminated and snow that is redistributed by wind action accumulates in small protected openings.

Snow depths and water equivalent were measured at both sites in April 1971. Average snow water equivalent was substantially higher in both clearcuts than in adjacent timbered sites.

At the ridge site, snow was deepest near the center of the cut plot and decreased toward both the east and west edges of the opening. The average water equivalent on the cut plot was 41 cm compared to 23 cm under the adjacent lodgepole stand. Maximum accumulation at the meadow site was along the downwind edge of the opening. Average water equivalent in the opening was 36 cm (slightly lower than at the ridge site), compared to 28 cm in the adjacent timber.

DISCUSSION

Soil water increased by as much as 11 cm in the surface 3 m of these glacial soils after cutting the lodgepole pine overstory. Treatment effects will gradually be reduced as the site once again becomes fully occupied by understory vegetation and trees. Natural invasion of vegetation on these sites appears to be slow; therefore, we might expect the treatment effects to persist for 10 to 20 years. Changes in water consumption following cutting lodgepole pine on these stony, glacially derived soils is less than that reported for volcanic soils in Washington and Oregon (Dahms 1971; Herring 1968). This fact may be attributed to differences in potential evapotranspiration, soil properties, and rooting characteristics.

Dietrich and Meiman (1974) reported an average increase in water content of 13.3 cm from small patch cuts in lodgepole pine in Colorado. Even though soils were different, the results compare quite favorably with soil water measurements reported in this paper for the drier site.

We did not anticipate the small differences in measurable soil water between plots on the meadow site. Differences in seasonal water withdrawal of only 3 cm between cut and uncut plots is not realistic and actual withdrawal by vegetation at the meadow site is probably much greater than indicated by this study. Water loss was not detected below the 1 m depth, the depth of the heavy clay layer, even though roots were observed at greater depths. Water loss at this site may be masked by continuous recharge from adjacent areas. If so, actual evapotranspiration would not be restricted by soil water deficit; so water loss should be higher than losses recorded at the drier ridge site.

Snow depth and water equivalent were substantially increased in the clearcuts, but melt rates are also higher in the open and snow disappeared at about the same date on all plots. There were no obvious changes in initial water content of the soils due to increased snow accumulation. Winter precipitation is usually adequate in this area to replenish soil water deficit on all but the most exposed, windy sites.

SUMMARY

This study has shown the feasibility of using mounted drilling equipment to install neutron access tubes in difficult stony soils. It has also provided a valuable measure of soil water relations to lodgepole pine growing on glacial tills. All moisture relations studies are site specific, but the study contributes to the ever-increasing evidence that timber harvesting can result in increased water yields.

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